

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
27 November 2003 (27.11.2003)

PCT

(10) International Publication Number
WO 03/098741 A1

(51) International Patent Classification⁷: H01Q 21/00, (74) Agent: CLARKE, A.; IP Qinetiq Formalities, Cody Technology Park, A4 Building, Room G016, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

(21) International Application Number: PCT/GB03/01886

(22) International Filing Date: 1 May 2003 (01.05.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0211161.5 16 May 2002 (16.05.2002) GB

(71) Applicant (*for all designated States except US*): QINETIQ LIMITED [GB/GB]; Registered Office, 85 Buckingham Gate, London SW1E 6PD (GB).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): PRICE, Sean [GB/GB]; Qinetiq Malvern, Malvern Technology Centre, St Andrews Road, Malvern, Worcs. WR 14 3PS (GB). COWARD, Peter, Russell [GB/GB]; Qinetiq Malvern, Malvern Technology Centre, St Andrews Road, Malvern, Worcs. WR14 3PS (GB). SALMON, Neil, Anthony [GB/GB]; Qinetiq Malvern, Malvern Technology Centre, St Andrews Road, Malvern, Worcs. WR14 3PS (GB).

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

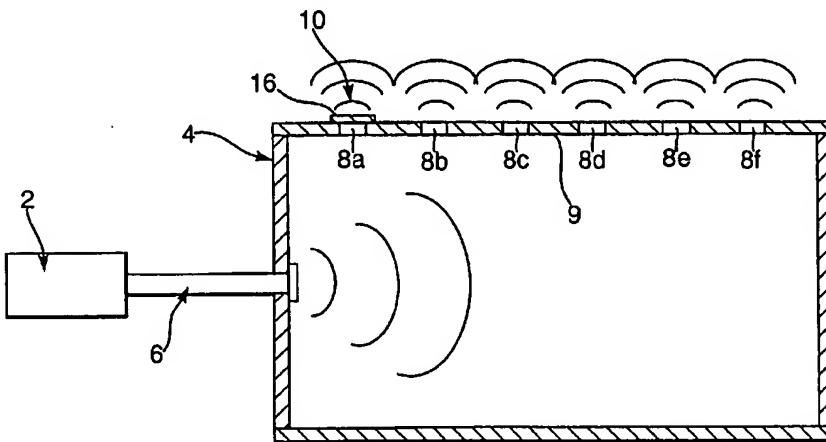
— *of inventorship (Rule 4.17(iv)) for US only*

[Continued on next page]

(54) Title: MILLIMETRE-WAVE ILLUMINATION SOURCE



WO 03/098741 A1



(57) Abstract: An illumination source of predominantly non-directional and incoherent millimetre-wave radiation for illuminating an area for passive millimetre-wave imaging comprises a container (4) with at least a partly reflective internal surface and a plurality of exit apertures (8) and a primary source (2) of millimetre-wave radiation for emitting millimetre-wave radiation into the container. The primary source and the container are arranged so that a proportion of the millimetre-wave radiation emitted by the source undergoes reflection within the container before being emitted through the apertures, such that the different path lengths are at least equal to the coherence length of the radiation. This is facilitated if the bandwidth of the radiation is preferably at least 1 GHz. The container may be a box in which a waveguide (6) is used to couple radiation from the primary source into the box. Alternatively, the container may be formed from a mesh and the plurality of holes is provided by the holes in the mesh.



Published:

— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Millimetre-Wave Illumination Source

The present invention relates to an illumination source for passive millimetre-wave imaging.

- Many available imagers for security applications can produce images which enable an operator to readily detect concealed weapons such as guns and knives, which are hidden for example within a person's clothing or baggage. Clothing and baggage materials are virtually transparent to at least some of these known imagers and this may be advantageous when metallic objects are solely of interest, since they will not be obscured by non-metallic material.
- 10 This does mean, however, that such imagers are not capable of providing recognisable images of passive non-metallic objects such as plastics, ceramics and explosives, which nowadays are often of more interest.

Millimetre-wave imaging addresses this problem. In outdoor passive millimetre-wave imaging high contrast is provided in the generated image by cold sky illumination. Depending on the geometry of the viewed scene, materials such as metals can reflect this illumination towards the imager, appearing cold and exhibiting a high contrast against the generally warm background. In addition, however, it is possible to use millimetre-wave imaging for detecting passive non-metallic objects, and this technique also allows the 20 remote and covert scanning of suspects.

Passive millimetre-wave imaging can be accomplished indoors but the lack of sky illumination means that the main source of contrast is now the actual temperature difference between objects. This contrast will be of the order of 10K, which is an order of magnitude less than what can be expected in outdoor 25 imagery.

Another alternative is to use an artificial source of millimetre-wave radiation, to illuminate the area being imaged in order to improve the contrast in the generated image. The relatively long wavelength of millimetre-wave radiation means that many reflections from visibly rough or dull surfaces are specular in

nature in the millimetre-wave portion of the electromagnetic spectrum, i.e. many visibly rough or dull surfaces behave similarly to a mirror to millimetre-wave radiation. This effect is noticeable when a person being imaged is illuminated from a small source. In this situation the person does not appear 5 uniformly warm in the generated image, but instead warm glints appear on the body of the person where specular reflection of the source from the body is incident on the aperture of the imager. This effect makes the generated image difficult to interpret in real time, particularly in real time.

This problem can be overcome by locating large areas of radar absorbent 10 material, for example over the walls, ceiling and floor of an indoor area in which passive millimetre-wave imaging is to be done and heating or cooling the radar absorbent material to a temperature that is different from the ambient temperature of the objects in the indoor area that are being imaged. Alternatively, large area portable panels of heated or cooled radar absorbent 15 material can be set up in the indoor area in which imaging is to take place. This approach requires a lot of energy to heat or cool the large area of radar absorbent material and does not lend itself to portability.

It would therefore be desirable to provide a non-directional illumination source 20 of millimetre-wave radiation, where the radiation also has a low degree of coherence, or no coherence, and which has relatively low power consumption. It would also be desirable to provide such an illumination source in the form of a uniformly radiating surface. Ideally the radiating surface would appear to have the same brightness at all angles of observation, so approximating a black body radiator.

25 In a first aspect the present invention provides an illumination source of millimetre-wave radiation for illuminating an area for passive millimetre-wave imaging, the source comprising a container with at least a part of its interior formed from reflective material and having a plurality of exit apertures; and a primary source of millimetre-wave radiation for emitting millimetre-wave 30 radiation into the container;

wherein the primary source and the container are arranged so that at least a portion of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container and each said aperture receives radiation from the source via at least two paths of different respective lengths.

- 5 Preferably the said at least two paths differ by more than the coherence length of said radiation, and since coherence length is dependent on bandwidth (a function of propagation speed over bandwidth), preferably the radiation has a bandwidth of at least 1 GHz. This provides a correspondingly low coherence length of around 30 cm, and higher frequencies give correspondingly shorter
10 coherence lengths.

Indeed, from another viewpoint, the requirement that the said at least two paths differ by more than the coherence length of said radiation is most easily met when the radiation has a large bandwidth. Furthermore, the millimetre-wave imager that would be looking at the illuminated scene is likely to have a
15 bandwidth in the GHz range, and the illuminating source would need to cover all of this bandwidth in order to make best use of the sensitivity of the imager.

Furthermore, using a wide bandwidth is one way of reducing the chances of dielectric layers not being visible due to interference effects.

Accordingly in a second aspect the invention provides an illumination source of
20 millimetre-wave radiation for illuminating an area for passive millimetre-wave imaging, the source comprising a container with at least a part of its interior formed from reflective material and having a plurality of exit apertures, and a primary source of millimetre-wave radiation for emitting millimetre-wave radiation with a bandwidth of at least 1 GHz into the container;

25 wherein the primary source and the container are arranged so that at least a portion of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container before being emitted through the apertures.

Preferably the bandwidth is at least 2 GHz, more preferably at least 10 GHz, and in some applications the bandwidth is 40 GHz or more. Relevant sources of radiation might be noise sources or amplifiers that amplify a noise source or load.

- 5 The source may be located entirely within the container, which provides a more self-contained arrangement. However, care then needs to be taken to ensure oscillation of the system cannot occur, for example if some of the radiation inside the container is fed back to the source via a leak in the structure (such as at a waveguide join) and re-amplified, which could well give rise to a change in
10 the source output and bandwidth and adversely affect the overall performance of the panel. One way of preventing radiation getting to the source components is to enclose them separately within the container with only the radiating aperture accessible.

One advantage of providing a source completely within the container is that it is
15 then much easier to tile a plurality of suitably shaped containers together to synthesise a larger illumination source without significant gaps.

Alternatively, the source or parts thereof may be outside the container and coupled thereto e.g. by a waveguide, a horn or a diffusive device such as a leaky waveguide. A diffusive device has the benefit of facilitating spreading of the
20 primary input radiation to more than one location within the container. An alternative form of diffusive device would be smaller version of the overall panel itself contained within the container. Preferably the device is selected such that it enables control of the level of radiation fed into the container.

The primary source is preferably arranged to act essentially as a point source,
25 for example by forming an input aperture to the volume of the container (whether from outside the container or from a source wholly within the container) which has a size approximating to the operating wavelength of the source.

Preferably the apertures have a width approximating to half the operating wavelength of the illumination source, so that the radiation emitted from the apertures spreads out with a solid angle approaching 2π steradians. As noted later, the beam patterns depend on polarisation and the direction of observation,

5 resulting in different E and H plane patterns, according to standard aperture theory. Care needs to be taken in selecting the hole dimension(s) insofar as when the dimension is small relative to wavelength the transmission through the hole varies as a high power of the dimension. This means that while reducing hole dimension(s) may improve the radiation pattern, in particular increasing its

10 width or angular range, the apparent or observed millimetre-wave temperature of the radiating surface (i.e. the surface incorporating the apertures) may fall to an undesired extent.

The apertures may all have the same shape and size, or the shape and/or size may vary (for example between 2 or 3 different discrete shapes or sizes, or there

15 may be a continuous variation in shape/size across the panel) to alter the overall pattern of radiation from the radiating surface.

In one embodiment the container is a box and a waveguide is used to couple millimetre-wave radiation from the primary source into the box. In another embodiment at least part of the container is formed from a mesh and the

20 plurality of holes is provided by the plurality of holes in the mesh.

The reflections that the radiation from the primary source undergoes before being emitted through the apertures in the container mean that some radiation from the source travels further within the container than other radiation before being radiated at a particular aperture. This helps to decrease the coherence of

25 the radiation emitted from the panel as a whole and from adjacent apertures in particular. Preferably over 50%, more preferably at least 75% and even more preferably at least 90% of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container before it is emitted through the apertures.

The incoherence of the emitted radiation may be further promoted where at least a part of the interior of the container is formed from rough reflective material so that incident light on the rough reflecting material is reflected in different directions. In this context "rough reflective material" means reflective 5 material with discontinuities of a size approximating or greater than the wavelength of the radiation. Also, by making the apertures small the emitted radiation pattern is broad, and therefore relatively non-directional (although it still has a definite maximum intensity direction).

Incoherence and non-directionality of the radiation from the apertures are two 10 of the requirements noted above for good indoor illumination for passive millimetre-wave imaging and they can be achieved by the present invention while consuming much less power than is required in the heating or cooling of large areas of radar absorbent material.

It is also very desirable that the power of the millimetre-wave radiation emitted 15 from each aperture in the container is similar so as to provide a uniformly radiating surface when viewed with a relatively low resolution (so as not to resolve individual apertures). This can be achieved in a variety of ways, such as by the careful arrangement of the pattern of the apertures formed in the container, by the use of at least one reflective baffle and/or at least one region of 20 millimetre-wave absorbing material within the container or by covering the apertures emitting the highest power millimetre-wave radiation by a partially reflective dielectric element or by a partially absorbing material.

In general, uniform radiation is assisted considerably by ensuring that the emitted radiation has undergone many reflections within the container, for 25 example by making the internal surface of the radiating surface more highly reflective and by careful control of aperture size and shape.

In addition the polarisation of the radiation emitted by the primary source relative to the radiating surface can be important. The E and H plane beam patterns of the apertures have an effect within the box as well, and it has been 30 shown to be desirable to choose that polarisation that is less likely to be directly

radiated, i.e. the one that corresponds to the H plane of the aperture, and is parallel to the plane of the radiating surface rather than perpendicular to it. Thus in Figure 10, which shows radiation fed from a waveguide 6 into the volume of a container defined in part by a continuous reflective surface 11 and 5 a reflective surface 9 including apertures 8, the source is arranged preferentially to provide the H-plane radiation component 7.

A further desirable feature would be that the radiating surface appears to have the same brightness at all angles of observation, so approximating a black body radiator. To this end, as will be explained in greater detail later, a low loss 10 dielectric material may be located at or immediately adjacent the apertures to intercept radiation passing through the apertures. Conveniently the dielectric material may take the form of a sheet of material over the exterior of the radiating surface, but other arrangements are possible.

A further use of a sheet of dielectric material over the radiating surface is to 15 control the direction of the radiation leaving the apertures. For example, the sheet may be wedge-shaped so as to refract the main radiation direction away from the normal; or the sheet may be stepped to act as a sort of Fresnel lens, for focussing or redirecting the radiation from the apertures depending on the pattern of the steps (e.g. a circular stepped pattern could be used for focussing 20 as in a Fresnel lens, but a linear stepped pattern could act as a wedge). In each case the sheet has a non-uniform thickness, and is preferable placed on the outside of the radiating surface.

Sources of GHz frequency radiation comprising a container with at least a part 25 of its interior formed from reflective material and having a plurality of exit apertures; and a primary source of millimetre-wave radiation for emitting millimetre-wave radiation into the container, in which the primary source and the container are arranged so that at least a portion of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container before being emitted through the apertures are known. For example, 30 UK Patent Application GB 2 233 502 A (Arimura Giken KK) discloses slot

antennae in which input radiation energy at 12 GHz for one polarisation and 14 GHz for the orthogonal polarisation is reflected into a rectangular waveguide having a slotted face, residual radiation being absorbed at the far end of the guide rather than being available for reflection. The description refers to power radiating from the slots "in equiphase", and to arranging the slot spacings according to the operative wavelength. There is a related disclosure GB 2 208 969 A (also Arimura Giken KK).

By contrast, the present invention is concerned with the provision of a broadband millimetre-wave illumination source and/or the provision of a source which radiates predominantly incoherent illumination.

The present invention extends to an array of illumination sources according to the first or second aspects of the invention, and to an imaging system comprising a millimetre-wave imager for imaging a predetermined region, and an array of illumination sources according to the first or second aspects of the invention arranged to illuminate said region.

In certain instances, it may merely be necessary to arrange the illumination sources either side of the region, for example in two opposed straight lines. However, unless the radiation from each source is uniform, some sources will contribute more radiation to the local region than others. Therefore, when the sources have a direction in which there is a maximum amount of radiated energy (the principal radiation direction) it is preferred to arrange the sources with their principal radiation directions generally directed towards the same more localised region. This can be done by inclining the sources relative to each other, and/or by arranging that the radiation from at least one source is refracted or steered as it leaves the radiating surface, for example as previously indicated by providing a dielectric wedge or linear stepped pattern on the radiating surface, for example. Additionally or alternatively, the radiation from one or more radiating surfaces may be "focussed" for example by providing a dielectric layer thereon having a circular stepped pattern much as in a Fresnel lens.

The present invention will now be described by way of example only with reference to the accompanying figures in which:

- Figure 1 shows a cross-section through a first embodiment of a source for passive millimetre-wave imaging according to the present invention;
- 5 Figure 2 shows a cross-section of a source for passive millimetre-wave imaging generally similar to that shown in Figure 1, but with an L-shaped cross-section;
- Figure 3 shows another embodiment of a source for passive millimetre-wave imaging according to the present invention employing a wire mesh;
- 10 Figure 4 is a plot of the variation of the observed or apparent temperature (in arbitrary units) of the radiating surface with observation angle for the E and H plane components for an illumination source such as that of Figure 1;
- Figure 5 is a drawing of a container of a modified illumination source according to the invention for explaining the effect of adding a sheet of low loss dielectric material over the radiating apertures;
- 15 Figure 6 is a theoretical plot of the variation of the observed or apparent temperature (in arbitrary units) of the radiating surface with observation angle for the E and H plane components for the container of Figure 5;
- 20 Figure 7 is a measured plot of the variation of the observed or apparent temperature (in arbitrary units) of the radiating surface with observation angle for the E and H plane components for a container similar to that of Figure 5;
- Figure 8 shows in schematic form a first imaging system incorporating a plurality of illumination sources according to the invention;
- Figure 9 shows in schematic form a second imaging system incorporating a plurality of illumination sources according to the invention and
- 25 Figure 10 illustrates the preferred mode of radiation injected into a container providing a source according to the invention.

In the arrangement in Figure 1 millimetre-wave electromagnetic radiation is generated in a millimetre-wave source 2, such as an amplified noise source and is coupled into a metal box 4 using waveguide 6. The source 2 will generate millimetre-wave radiation associated with a temperature which is either much 5 higher or much lower than the ambient temperature of the objects in the area being imaged. In this way higher contrast can be introduced into the generated image. The metal box 4 has an internal reflective surface which may, for example, have a reflectivity of 0.5 or greater at the operating wavelength. At least one side of the box 9 is formed with an array of through holes or apertures 10 8, which may for example be circular, six of which (8a-8f) can be seen in Figure 1. Normally the array will be two-dimensional, although the use of a one-dimensional or linear array also falls within the scope of the invention. The waveguide 6 has an aperture at its end remote from the source 2 having a diameter approximating the operating wavelength of the radiation generated by 15 the source 2. Thus, the radiation from the waveguide 6 spreads out on entry into the box 4 with a solid angle approaching 2π steradians, so that the end of the waveguide 6 effectively acts as a point source.

Some of the radiation emitted from the end of the waveguide into the box 4 will travel directly to one of the holes 8 but the majority of the radiation will 20 undergo at least one reflection at the internal surface of the box 4 before reaching a hole. The holes 8 each have a diameter approximating to half of the wavelength of the radiation generated by the source 2 and so the radiation emitted from the holes will spread out with a solid angle approaching 2π steradians. This is shown for example by the wavefronts 10 of the radiation 25 emitted from the hole 8a.

The millimetre-wave radiation can have a coherence length of the order of several tens of millimetres depending on its bandwidth. The dimensions of the box 4 are chosen so that when internal reflections are taken into account the path length differences of radiation travelling between the source and each hole 30 8 will tend to be equal to or greater than its coherence length, thus ensuring that interference effects from the millimetre-wave radiation emitted by the holes 8

will be insignificant. Also, due to the small size of the holes 8 the radiation emitted from the holes will be non-directional. The side of the box 4 in which the holes 8 are formed itself forms a radiating panel or radiating surface which can be part of a one or two-dimensional array of such radiating panels located at 5 or around an area which requires millimetre-wave illumination.

For satisfactory illumination, preferably all reflections off the surface of the object being observed which are seen by a millimetre-wave imager observing the illuminated scene should originate at an illuminated panel, either directly or via other reflections. Each illuminating panel preferably has a constant average 10 radiation temperature across its surface and will be capable of radiating into a large solid angle. Where the illuminating panel makes use of a plurality of radiating apertures, those apertures should preferably be sufficiently close together that they cannot be resolved by the imaging system when used for imaging an object illuminated by the panel (i.e. the panel has a uniform 15 appearance when viewed as reflected by the object being imaged. The imaging system is not normally focussed on the panel itself.) This will ensure that the observed radiation temperature is approximately constant across the surface of the panel. Similarly, gaps between adjacent panels can be accommodated provided they are not resolvable by the imaging system when used to image an 20 object illuminated thereby.

Where a non-portable millimetre-wave source is required, the box 4 could be formed with holes in only one of its sides and the walls, floor and/or ceiling of an indoor area where the imaging is to take place can be at least partially tiled with a plurality of such sides of such boxes. Using an arrangement of such 25 boxes according to the present invention will use significantly less energy than would be required to heat or cool the equivalent area of radar absorbent material.

Where a portable version is required, one or more such boxes with holes formed a suitable number of its sides could be located at or around the area where the 30 imaging is to take place. While the originally intended use of these panels was

for indoor locations, they could also be used outside to provide illumination for other passive millimetre wave systems, including those at outdoor locations.

- Ideally, the radiation intensity from each aperture has the same value. If it is found that the intensity of radiation is higher from some holes, for example
- 5 holes closer to the source 2, then partially reflective dielectric could be used to cover these holes, for example the dielectric 16 located over the hole 8a in Figure 1 which is closest to the source 2. Alternatively or additionally, some absorbing material, such as radar absorbent material, could be fitted over part of the internal or external surface of the box.
- 10 The pattern of holes used can be adjusted to make the illumination from the box 4 as uniform as possible, so to produce a more uniform average temperature profile across the surface of the box containing the holes 8. In addition or alternatively, reflecting baffles, dielectrics or absorbers could be located within the box or on the internal surface of the box in order to alter the radiation
- 15 pattern generated by the box, and/or the primary source location or aperture type may be appropriately adjusted.

The embodiment of Figure 2 shows that the box need not be of simple rectangular cross-section. As shown, the box 4 has an L-shaped cross-section with the source 2 and waveguide 6 located at one end of the L and a optionally

20 reflecting baffle 12 located at the bend in the L, but other shapes of box could be employed. Where present the reflecting baffle 12 could have a rough reflecting surface in order to further decrease the coherence of radiation emitted from the box 4. By "rough reflecting surface" is meant a reflecting surface with irregularities on a scale equal to or greater than the wavelength of the radiation.

25 The radiating holes are formed for example in the end 4a of the box 4 where not obscured by the baffle 12. In this embodiment, radar absorbent material absorbing material 14 is fitted over selected areas of the interior of the box to render the outputs of the apertures 8 more uniform.

A further embodiment of the present invention is shown in Figure 3, in which

30 the illuminating source for indoor passive millimetre-wave imaging comprises a

millimetre-wave source 22 and a container in the form of a dome 24 made of mesh which has a flat base 30 with a reflecting upper surface. The source 22 is located at the centre of the dome 24 and has an aperture 26 on its upper surface. The size of the aperture 26 is of the order of half of the operating wavelength of
5 the source so that the source radiates over a wide solid angle. The underside of the mesh which forms the dome is reflective and may be formed from reflective metal. The base 30 may also comprise a metal sheet with a reflective upper surface. The spacing of the strips or wires making up the mesh is preferably less than half the operating wavelength of the source 22. Due to this spacing of
10 the strips or wires making up the mesh a large proportion of the radiation will be reflected by the underside of the mesh at least once before it is emitted through the mesh. The spacing of the strips or wires forming the mesh can be used to control the proportion of the radiation reflected from the mesh before it is emitted through the mesh. The architecture of the dome 24 will cause the
15 majority of radiation from the source 22 to be reflected a large number of times within the dome which will destroy the coherence of the radiation from the source. Using a rough reflecting surface as the upper surface of the base 30 or baffles within the dome can further reduce coherence.

Thus the mesh dome 24 radiates as a spatially incoherent source in all directions
20 with a substantially uniform intensity.

Again, however, if necessary, areas of the container may be covered with radar absorbent material, for example on the base 30, and/or selected areas of the mesh may be covered with a partially reflecting dielectric sheet.

It should be noted that the sources of Figures 1 to 3 may be arranged to emit
25 both horizontally and vertically polarised radiation. This can be used to further improve contrast in a millimetre-wave imaged scene if images are taken separately using the differently polarised radiation and then processed.

As noted previously, a further desirable feature would be that the radiating surface appears to have the same brightness at all angles of observation, so
30 approximating a black body radiator.

For this to occur, all the individual radiating elements (apertures) would need to have a cos theta radiation pattern, dropping to zero at a 90 degree incidence angle. Such a pattern would cancel out the $1/(\cos \theta)$ increase in area, as seen by a beam of constant solid angle, as the angle of observation of a notional 5 infinite surface moves away from normal.

However, the radiation pattern from circular or rectangular holes does not follow this law, and, indeed, the E and H patterns are not equal, so that the surface will appear to be at different temperatures depending on the observation direction. This is shown in Figure 4, which is a modelled curve for a circular 10 hole, found to agree closely with experiment. Thus in reality the apparent surface temperature drops with increasing angle in the H plane, curve 32, because the H plane radiation from a circular hole is narrower than the ideal cos theta pattern, but rises in the E plane, curve 34, because the E-plane radiation is wider than the ideal. The ideal behaviour would be the same horizontal line for 15 both E and H plane radiation.

If low loss dielectric material 18 such as polythene is placed over each aperture 8, Figure 5, conveniently as a continuous sheet but optionally as individual components for each aperture, the emitted radiation from the aperture will be refracted, bending rays away from the normal. Thus some radiation 19 emitted 20 at a large angle to the panel normal which would have been emitted is now totally internally reflected in the dielectric, and is either passed back into the container 4 or, more probably retained within the dielectric 18 and eventually absorbed or emitted along the edges of the panel or over its entire surface at a different angle to the normal. Radiation 20 that travels through the dielectric 25 sheet at an angle of incidence between its critical angle (ray 21) and its normal is now spread out over the full 90 degree range as it leaves the aperture.

The effect on the emitted radiation pattern is shown in Figure 6, and it will be seen that the E-plane radiation pattern 36 is now very much flatter, and the H pattern 38 is improved, although it still falls with increasing angle.

A similar effect is shown in Figure 7 for a panel with 5 mm diameter holes on a 50 mm square pitch. The arrows E and H respectively indicate the effect on the apparent or observed temperatures of the E and H components on adding a 10 mm thick polythene sheet to the surface.

- 5 Figure 8 shows an imaging arrangement comprising a millimetre-wave camera 40 for viewing a subject 42 in a local imaging region between opposed rectilinear lines of illumination sources 44 according to the invention. Although the sources could be used without any modification, as shown the sources more remote from the subject are provided with dielectric wedges on their radiating
10 surfaces so as to deflect by refraction the radiation closer to the subject.

- Figure 9 shows an alternative imaging arrangement in which the more remote sources 44 are inclined relative to the closer sources so that the normal to the radiating surface of each source is generally directed towards the subject. Naturally, both a geometrical arrangement such as in Figure 9 and beam
15 deflection for example as in Figure 8 may be employed conjointly to obtain the optimum illumination of the subject.

- Where there is a plurality of sources 44, they may be arranged to be individually or separately controlled, for example to turn on each one, or each group of sources, independently of each other. This will alter the radiation
20 pattern received by the subject, and may show up 'shadowing' effects of objects and provide useful additional information.

- It should be noted that, especially if a panel is being reflected in something as well as directly illuminating a person or object, the principal radiating direction may not be the direction of the person or object. Similarly, where as in Figure 9
25 there is a plurality of relatively inclined sources, they may alternatively be arranged so that their principal radiating directions converge at a locality which is not coincident with the position of the object.

Although Figures 8 and 9 show a plurality of sources 44, a single source could be used in some instances. Whether there is one source, or a plurality, the

pattern of radiation at the subject may be further adjusted or controlled by providing one or more additional reflectors external to the source(s), such as a mirror or diffuser.

A panel may be strengthened (e.g. for standing on) by using dielectric or metal
5 materials within it, without adversely affecting its performance.

Claims

1. An illumination source of millimetre-wave radiation for illuminating an area for passive millimetre-wave imaging comprising a container with at least a part of its interior formed from reflective material and having a plurality of exit apertures; and a primary source of millimetre-wave radiation for emitting millimetre-wave radiation into the container;
wherein the primary source and the container are arranged so that at least a portion of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container and each said aperture receives radiation from the source via at least two paths of different respective lengths.
10
2. An illumination source according to claim 1 wherein said at least two paths differ by more than the coherence length of said radiation.
3. An illumination source according to claim 1 or claim 2 wherein the radiation has a bandwidth of at least 1 GHz.
15
4. An illumination source of millimetre-wave radiation for illuminating an area for passive millimetre-wave imaging comprising a container with at least a part of its interior formed from reflective material and having a plurality of exit apertures; and a primary source of millimetre-wave radiation for emitting millimetre-wave radiation with a bandwidth of at least 1 GHz into the container;
wherein the primary source and the container are arranged so that at least a portion of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container before being emitted through the apertures.
20
5. An illumination source according to any preceding claim wherein a portion of the radiation is not reflected before being emitted through the apertures.
25
6. An illumination source according to any preceding claim wherein the majority of the millimetre-wave radiation emitted by the primary source undergoes reflection within the container before being emitted through the apertures.

7. An illumination source according to any preceding claim wherein at least one reflective baffle is located within the container.
8. An illumination source according to any preceding claim wherein at least one region of millimetre-wave absorbing material is located within the
5 container.
9. An illumination source according to any preceding claim wherein at least one of the exit apertures is covered by a partially reflective dielectric element.
10. An illumination source according to any preceding claim wherein the primary source is substantially a point source.
- 10 11. An illumination source according to any preceding claim wherein the source is coupled to the container by a waveguide.
12. An illumination source according to any preceding claim wherein the source is located within the container.
13. An illumination source according to any preceding claim wherein the
15 container is a box.
14. An illumination source according to any one of claims 1 to 12 wherein at least part of the container is formed from a mesh and the plurality of apertures are formed by the holes in the mesh.
15. An illumination source according to claim 14 wherein the container
20 comprises a dome of mesh located over a base having a reflective upper surface.
16. An illumination source according to claim 14 or claim 15 wherein the mesh is made from metal wire.
17. An illumination source according to any preceding claim wherein the apertures have a width approximating to half the operating wavelength of the
25 illumination source.

18. An illumination source according to any preceding claim wherein a low loss dielectric material is located at or immediately adjacent the apertures to intercept radiation passing through the apertures.
19. An illumination source according to claim 18 wherein the low loss dielectric material is in the form of a sheet on a surface of the container incorporating the apertures.
20. An illumination source according to claim 18 or claim 19 wherein the low loss dielectric material has a non-uniform thickness to control the direction of the radiation leaving the apertures.
- 10 21. An illumination source substantially as hereinbefore described with reference to any one of the accompanying Figures.
22. An imaging arrangement comprising a millimetre-wave imager for imaging a local region and at least one illumination source according to any one of claims 1 to 21 arranged for illuminating said region.
- 15 23. An imaging arrangement according to claim 22 and including a plurality of said sources.
24. An arrangement according to claim 23 wherein the sources have a preferred principal radiation direction and are arranged so that their principal radiating directions converge.
- 20 25. An imaging arrangement according to claim 22 or claim 23 and including means for selectively controlling one or more said sources whereby to alter the radiation pattern received at said local region.
26. An arrangement according to any one of claims 22 to 24 and also including at least one passive millimetre-wave reflector for altering the pattern of radiation received by the said local region from the said source.
- 25 27. An arrangement according to claim 25 wherein said passive device is a mirror or diffuser.

1/4

Fig.1.

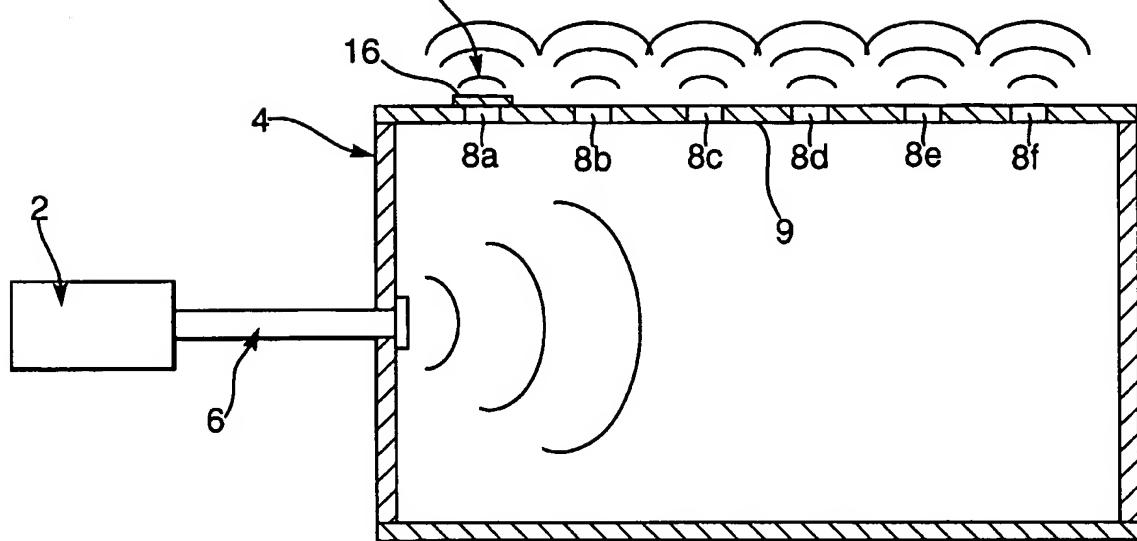
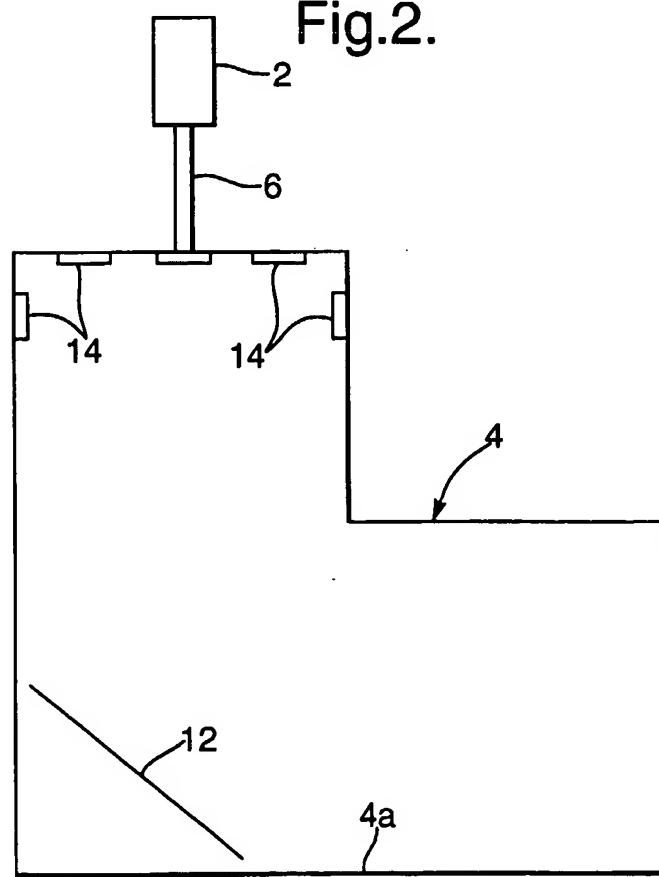


Fig.2.



2/4

Fig.3.

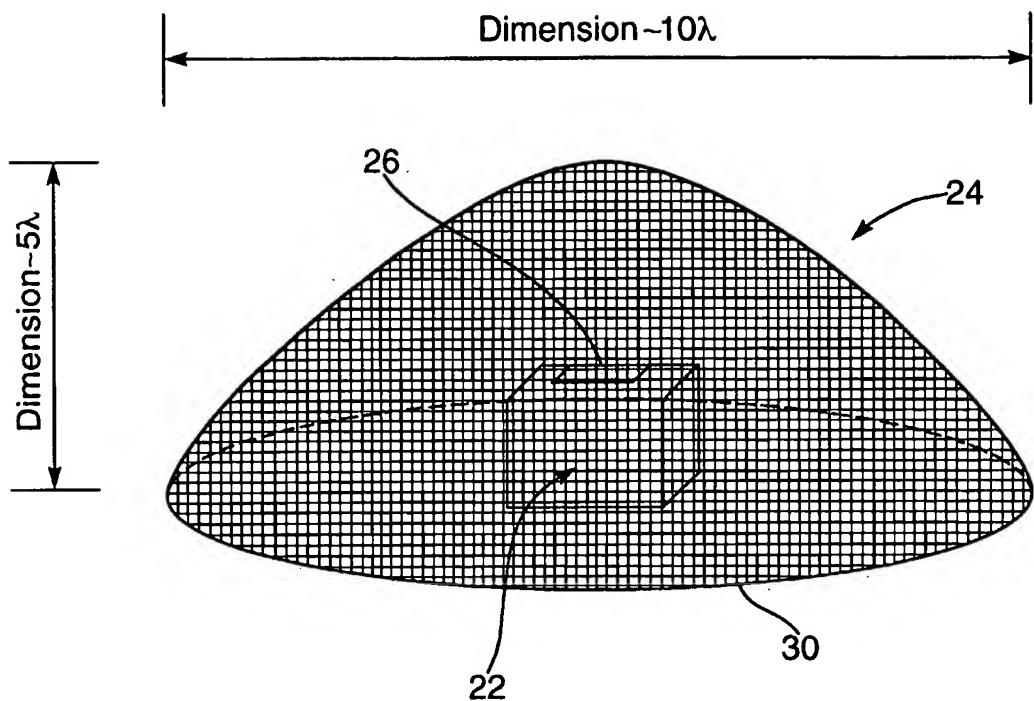
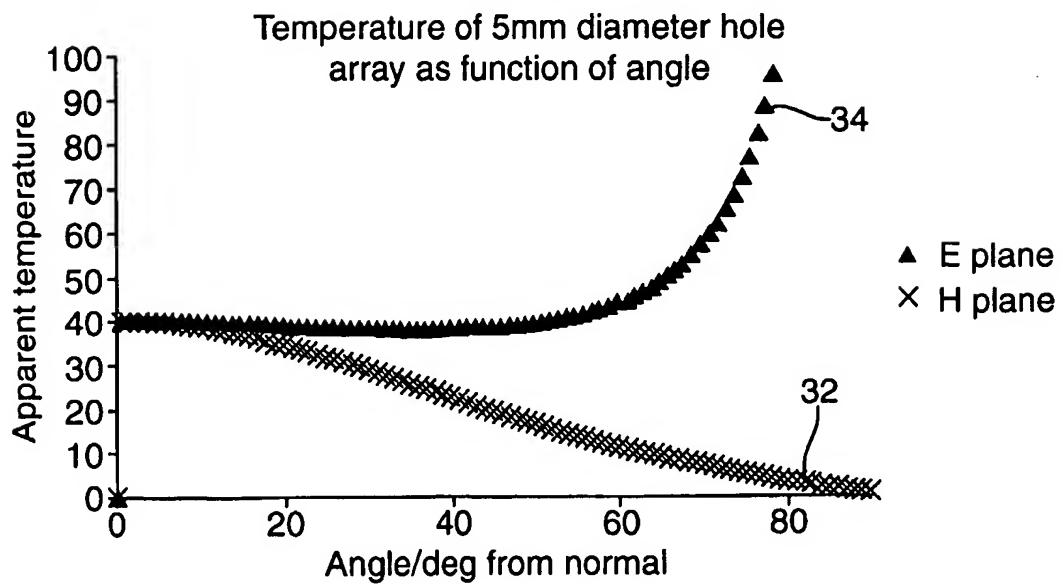
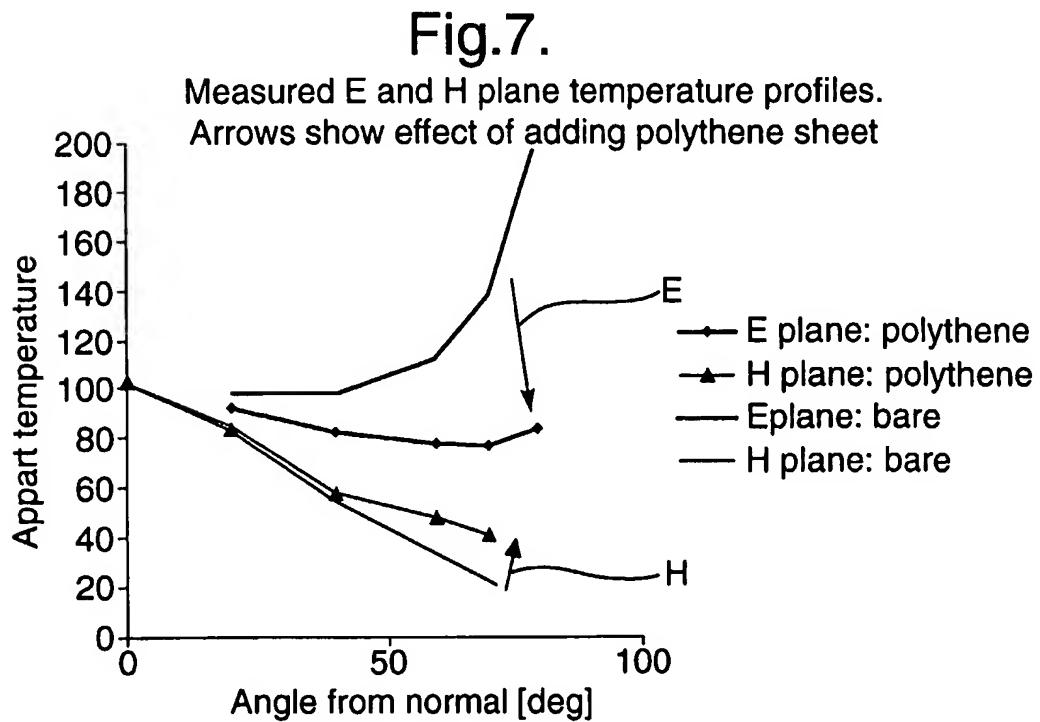
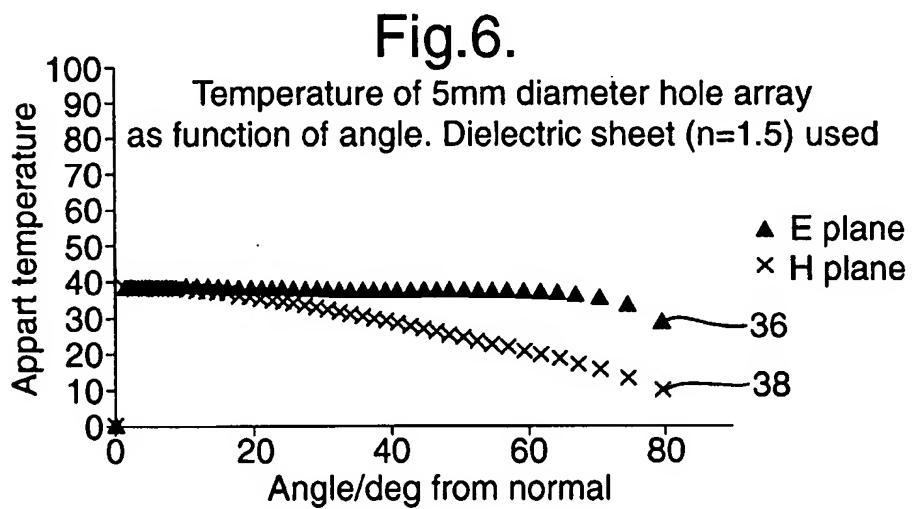
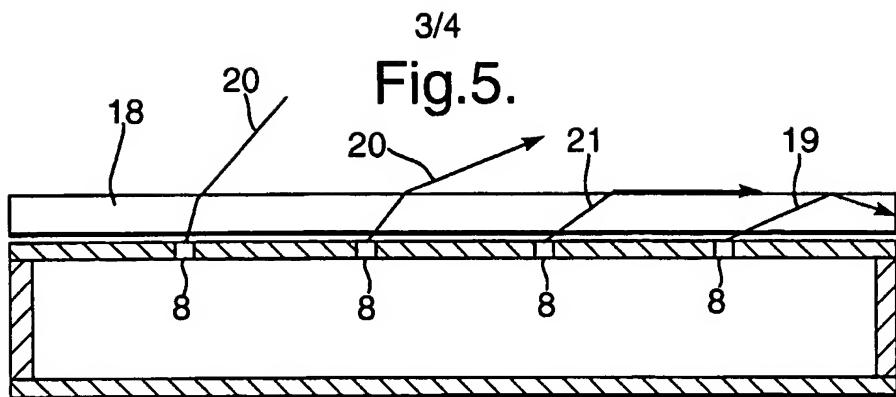


Fig.4.





4/4

Fig.8.

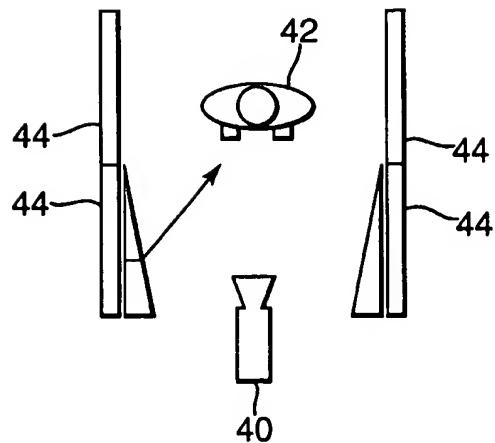
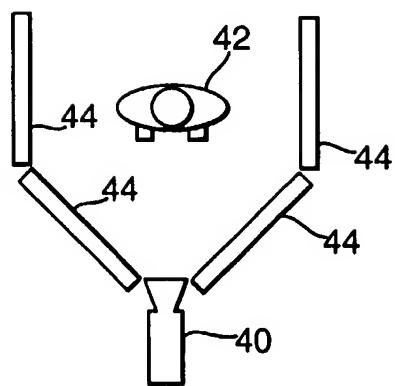


Fig.9.



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 03/01886

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 H01Q21/00 H01Q21/06 H01Q13/18 G01V8/00 G01V3/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 IPC 7 H01Q G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 173 714 A (TSUKADA AKIRA ET AL) 22 December 1992 (1992-12-22) cited in the application figure 13 ---	1-27
A	FR 2 619 658 A (ARIMURA INST TECHNOLOGY) 24 February 1989 (1989-02-24) cited in the application figure 24 ---	1-27
A	US 5 680 139 A (MOORE ELLEN L ET AL) 21 October 1997 (1997-10-21) the whole document ---	1-27
A	WO 90 07130 A (MILLITECH CORP) 28 June 1990 (1990-06-28) abstract -----	1-27

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *&* document member of the same patent family

Date of the actual completion of the international search

18 August 2003

Date of mailing of the international search report

25/08/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Wattiaux, V

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 03/01886

Patent document cited in search report	Publication date		Patent family member(s)	Publication date
US 5173714	A 22-12-1992	JP DE FR GB	2302104 A 4015765 A1 2647269 A1 2233502 A	14-12-1990 22-11-1990 23-11-1990 09-01-1991
FR 2619658	A 24-02-1989	JP JP JP CN DE FR GB KR	1048503 A 1062003 A 2595260 B2 1031451 A ,B 3827956 A1 2619658 A1 2208969 A ,B 9108948 B1	23-02-1989 08-03-1989 02-04-1997 01-03-1989 02-03-1989 24-02-1989 19-04-1989 26-10-1991
US 5680139	A 21-10-1997	US AU WO	5455589 A 1598095 A 9518980 A1	03-10-1995 01-08-1995 13-07-1995
WO 9007130	A 28-06-1990	US WO CA US US	5073782 A 9007130 A1 1338522 C 5047783 A 5227800 A	17-12-1991 28-06-1990 13-08-1996 10-09-1991 13-07-1993